Fundamental Considerations for Ultrasound-Guided Musculoskeletal Interventions

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KEYWORDS

• Image guidance • Injection • Musculoskeletal • Sonography • Ultrasound
• Ultrasound-guided injection

KEY POINTS

- Ultrasound can be used to guide joint and soft tissue interventions to improve accuracy, efficacy, patient satisfaction, and to minimize complications.
- An understanding of ultrasound principles and techniques is critical to performing any ultrasound-guided procedure.
- Appropriate preparation allows the physician to safely and effectively perform ultrasound-guided procedures.

INTRODUCTION

Ultrasound use has expanded exponentially in the musculoskeletal arena in recent years for several reasons, including improved safety, portability, decreased cost, and lack of ionizing radiation.[1] In regard to joint and soft tissue injuries, ultrasound is useful for differentiating between acute injuries, chronic disease, and normal anatomic variations. Further, the practitioner can guide a procedure for the treatment of musculoskeletal disease by following the placement of the needle in real time.[2] However, to appreciate and understand the benefit and rationale of ultrasound-guided (USG) injections, the practitioner must have a basic understanding of the ultrasound machine system.

The process of obtaining an ultrasound image begins with the reverse piezoelectric effect.[3,4] The ultrasound machine sends a pulsed electrical signal to the transducer

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crystals, which transforms that energy into an intermittent acoustic wave, a form of mechanical energy. These sound waves are then transmitted to the tissues via a sonoconductive gel. The acoustic waves interact with tissue and some waves will be reflected back to the transducer, whereas others are absorbed and refracted. The reflected intermittent acoustic waves return to the transducer and are then converted via the direct piezoelectric effect to an electrical signal.[3,4] This electrical signal is then translated into an image on the ultrasound screen. Different transducers with varying crystal properties and thickness determine the frequency of the acoustic wave (see later discussion).[5,6]

Structures that are perpendicular to the transducer will create an angle of insonation of approximately 90°, optimizing the image. Maximizing the reflection produces a bright (hyperechoic) image. Structures with less reflective interfaces will produce a darker (hypoechoic) image. The interface between structures that have very different impedances may also appear hyperechoic, whereas structures with similar impedances may be isoechoic, or of similar echogenicity (overall brightness in sonographic appearance). Furthermore, it is important to realize that ultrasound images are based on the relative material properties of a tissue and its adjacent tissues rather than solely on the properties of that tissue in isolation.[6] Finally, some structures, such as bone, allow no echoes to extend deep to their surfaces and, therefore, the area beneath the surface, or acoustic interface, will appear black from shadowing, also referred to as anechoic (absence of echoes).[5]

Rationale for Ultrasound Guidance for Procedures

Joint and soft tissue injections have been a cornerstone of musculoskeletal medicine and the growth of ultrasound has made many of those injections more accurate and efficacious. Injection accuracy is defined as placing the needle tip and, if desired, injectate into the intended structure.[7] Palpation-guided (PG) injections are more likely to result in adverse effects, including hemarthrosis, septic joint, postinjection pain, and systemic effects.[8] Accuracy may be particularly important when injecting an orthobiologic substance, such as platelet-rich plasma or mesenchymal stem cells, in which precise accuracy of injectate placement is paramount to achievement of its proposed benefit.[1]

Limitations of Palpation-Guided Injections

In addition to potential inaccuracy relative to USG injections, a limitation of PG injections is a possible greater risk of injury to nearby structures. For example, PG injections into the glenohumeral joint are at risk of penetrating the long head of the biceps tendon.[9] Although many clinicians may be confidant in their PG injection technique, many structures are surprisingly difficult to palpate accurately. For example, the accuracy rate for palpation of the biceps tendon in a small group of physicians was only 5%.[10] This investigation found that physicians typically palpated medial to the biceps tendon, often over the subscapularis tendon, making a PG injection in this region potentially unfavorable for both intended therapeutic effect and safety. Furthermore, accuracy rates for PG biceps tendon sheath injections have been found to be 27% compared with 87% with USG injections.[11]

The hip joint is a common source of disease and lies in close proximity to significant neurovascular structures. Injecting the hip joint without imaging carries risk of injury to the femoral nerve, among other vital structures. In PG intra-articular hip injections via the anterior approach, the needle pierced or contacted the femoral nerve in more than a quarter of injections and came within 5 mm in almost two-thirds of the injections.[12]